W. B. Fow...

AN INTRODUCTION TO LINEAR DRAWING.

TRANSLATED FROM THE FRENCH OF

M. FRANCŒUR,

AND ADAPTED TO THE USE OF

PUBLICK SCHOOLS IN THE UNITED STATES.

By WILLIAM B. FOWLE,
INSTRUCTER OF THE MONITORIAL SCHOOL, BOSTON.

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DISTRICT OF MASSACHUSETTS, TO WIT:

DISTRICT CLERK'S OFFICE.

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"An Introduction to Linear Drawing. Translated from the French of M. Francœur, and adapted to the use of Publick Schools in the United States. By William B. Fowle, Instructer of the Monitorial School, Boston."

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INTRODUCTION.

An elementary treatise on Drawing, adapted to the use of common schools, cannot but be well received. Besides the professions which make the art of drawing their particular study, anatomists, naturalists, mechanicks, travellers, and indeed all persons of taste and genius, have need of it, to enable them to express their ideas with precision, and make them intelligible to others.

Notwithstanding the great utility of this branch of education, it is a lamentable fact, that it is seldom or never taught in the publick schools, although a very large proportion of our children have no other education than these schools afford. Even in the private schools where drawing is taught, it is too generally the case that no regard is paid to the geometrical principles on which the art depends. The translator appeals to experience when he asserts, that not one in fifty of those who have gone through a course of instruction in draw-

ing, can do more than copy such drawings as are placed before them. Being ignorant of the certain rules of the art, (and they are the most certain because mathematical) they are always in leading strings, and, unless endowed with uncommon genius, never originate any design, and rarely attempt to draw from nature. It is to remedy this defective mode of teaching, that the translator has been induced to present this little work on the elements of drawing, to the American publick.

Most of our faculties, when exercised, may attain to a surprising degree of perfection. A precision may be acquired by the eye and hand, almost equal to that of ordinary instruments. With this view, the society for the improvement of elementary instruction in France, directed some of their most distinguished members to procure a work on the art of drawing, which should be applied to the system of mutual instruction, there the national system. The following treatise is, in a great measure, a translation of that approved by them. It is not intended for a treatise on the art in all its numerous branches, but merely the *linear*, and, of course, the fundamental and most useful part of it.

The geometrical figures are arranged according to the difficulty of their execution, rather than in the order of theorems.

Each figure is accompanied with suitable explanations, so that the teacher or monitor will easily comprehend them, and be able to teach them to his classes, without much previous acquaintance with the art.

The pupils are each furnished with a slate and pencil. The monitor directs what figure shall be drawn, and if the pupils are not all furnished with this treatise, he chalks the figure on a board, painted black for the purpose, and suspended where all can see it. The slates are then examined by the monitor, and precedence is given to whichever pupil has executed the figure best.

The instructer should select a sufficient number of the most skilful for monitors, who should be under his immediate instruction. As soon as they have become expert in drawing the figures of the first class, a second may be formed to be instructed by the first class, (which now becomes the second) and so on to the sixth. The highest class under the master, may consist of about fifteen pupils. The lower classes may consist of any number, but for every six or eight scholars there should be a monitor.

The first class draw right lines, angles, parallels, perpendiculars and triangles.

The second class draw polygons, and polyedrons, or solid figures of many sides.

The third class make circles, and *regular* polygons.

The fourth draw a protracter, make angles of a given opening, draw ellipses, cylinders, cones, spheres, &c.

The fifth apply the preceding figures to architectural drawings, vases, and tasteful ornaments.

The sixth class draw the orders of architecture, and such other objects as an ingenious instructer shall direct.

If the school do not consist of more than 30 or 40 pupils, there will be no need of employing as monitors any but the highest class.

The children should not be permitted to draw on *paper*, until they have become thoroughly acquainted with the figures of the five first classes. Before they attempt the sixth, they may be permitted to review the five preceding classes, drawing the figures on paper with a lead pencil.

The pupils are not to be allowed the use of a rule, or any other instrument; but the monitor, to correct and prove their figures, may be furnished with a rule, dividers, square, and protracter or graduated semicircle. The rule should be a good one, with the inches and tenths of inches marked on it, that, when the pupils have become expert in making the figure, the difficulty may be increased by requiring the whole, or some part of the figure, to be of a given length or dimension.

On most rules in common use, the inches are divided into quarters and eighths, but as it is our plan to apply Geometry to *decimal* arithmetick, such rules as are divided into tenths should be preferred. When the simplicity of decimal calculations is so evident, it is to be regretted that *all* our *measures* are not subdivided into decimal parts, as our *currency* is, and why our government should set so good an example in one particular, and neglect all the rest, it is not easy to determine.

Although this treatise was originally designed for schools of mutual instruction, still a slight examination

of it will show that there is nothing which unfits it for use in schools on any other plan. If the pupils are all taught, and their drawings examined by the instructer, they will do well; but if they are likewise required to examine and correct each other's work, they will do better; they will acquire a familiarity with the figures, and an exactness in execution, to which mere *learners* seldom attain.

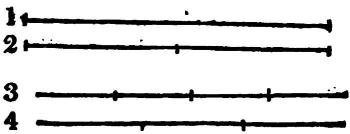
CONTENTS.

TREATISE

ON

LINEAR DRAWING.

FIRST CLASS.



The first class only draw right lines, triangles and perpendiculars. The corrections are made with a rule, and dividers.

The four first figures drawn above, relate particularly to the first eight propositions. To ascertain if the line be straight, let the monitor draw a line through it or near it with a rule. To ascertain if a line be cut into equal parts, measure the parts with the dividers, if the eye be not sufficiently practised to detect the errours without their assistance.

PROPOSITIONS.

1. *Draw a right line (that is, a straight line.)* fig. 1.
2. *Draw a right line and divide it in the centre.* fig. 2.
3. *Draw a right line and cut it into quarters.* fig. 3.
4. *Draw a right line and lengthen it as much farther.* fig. 2.

5. *Draw a right line and continue it twice its length.* (fig. 4.)

6. *Draw a right line and lengthen it three times its length.* (fig. 3.)

7. *Cut a right line into three equal parts.* (fig. 4.)

8. *Cut a right line into six or eight equal parts, and so on.*

It will be a useful exercise at this stage of the business, to show the parts of a line when divided. Thus, if required to show how much three quarters of a line are, the pupil must find one quarter, and the rest of the line will be three quarters. To find three fifths of a line, cut the line into five parts, and take three of them. A very correct idea of fractions may in this way be communicated.

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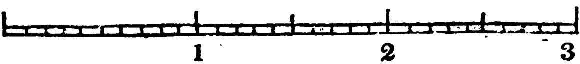

9. *Draw a line one inch long, then two, three, four, five, six.* (fig. 5.)

10. *Draw a line and divide it into inches.*

It is of no consequence what the length of the line is. Begin at the left, and mark as many whole inches as there may be.

(6)


11. *Draw a horizontal line.*

A horizontal line is one drawn from left to right, or from right to left. The surface or top of a bowl of water is horizontal or level.

12. *Draw a perpendicular line.* (fig. 6.)

A perpendicular or vertical line is one perfectly upright, as a string will hang from a nail, or from the hand, with a weight at the end of it.

In making horizontal lines, the pupil should make them parallel to the top or bottom of his slate or paper, and in making perpendiculars they should be parallel to the sides of the slate or paper. *Parallel* lines are lines running in the same direction equally distant from each other in every part; thus, the horizontal lines in figures 1, 2, 3, 4, are parallel to each other. Lines may be drawn parallel at any distance from each other.

13. *Draw two parallel horizontal lines, then three, four, five and six.*

14. *Draw two parallel perpendiculars, then three, four, five and six.*

15. *Draw an oblique line, and cut it into two, four, three and six parts.*

An oblique line is one between a horizontal and a perpendicular; that is, a *leaning* line.

16. *Draw two parallel obliques, then three, four, five and six.*

17. *Draw parallel lines an inch apart, then half an inch, a quarter, &c.*

18. *Draw a perpendicular, and cut it into two, three, four, five, six equal parts.*

It is difficult to cut a *perpendicular* into equal parts, because of an optical deception which leads us to think the upper parts shorter than they really are. This errour must be guarded against.

19. *Join two dots or points by a right line.*

The pupil will move his pencil two or three times from the left dot to the right, before he draws the line. This precaution is more necessary when the operation is performed on paper than when on a slate, where it may be erased if wrong.

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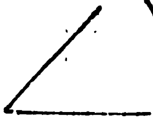
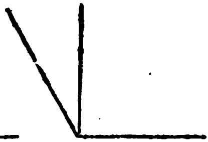




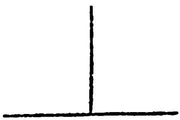
(8)

20. *Make an acute angle.* (fig. 7.)

Care must be taken to distinguish an *angle* from what is called its *point* or *apex*. The *angle* is the *opening* between two lines that meet, and the *point* or *apex* is the point where the lines meet. A pair of dividers forms a number of different angles, by being opened more or less.

It is this *opening* of the sides which determines the size of the angle, and not the *length* of the sides, which if lengthened out ever so far would not affect the size of the angle.

(9)



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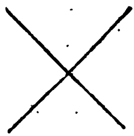
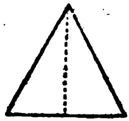


Imagine two lines which cross each other as in figures 9 and 10. They will make four angles. These are *right* angles if they are *equal*, and they will be equal if one line is perpendicular to the line it crosses. If the angle be *less* than a *right* angle, it is called an *acute* angle; if more, it is called an *obtuse* angle. *Acute* means sharp, and *obtuse* means blunt.

21. *Make an obtuse angle.* (fig. 8.)

22. *Make an acute angle with the opening turned upward, downward, to the right and to the left.* (Make but one at a time.)

23. *Make a triangle.* (fig. 11.)

(11) 

Close the space between the sides of an angle with a right line, and you make a triangle, a figure which has three angles and three sides.

The *base* is the side on which the triangle is supposed to rest.

The *apex* of a triangle is the point opposite to the *base*.

The *height* of a triangle is a perpendicular drawn from the *apex* to the *base*. In the figure it is shown by the dotted line.

A triangle is called *Isoceles* when two sides are equal. If all three of the sides are equal, it is *Equilateral*, (which word means *equal-sided*); and, if all the sides are unequal, it is called *Scalene*.

24. *Raise a perpendicular on a horizontal.* (fig.9.)

This will produce *right angles*, as we have before remarked. To ascertain if the angle be exact, take a piece of what is called bonnet paper or thin pasteboard, cut it round, and then cut the round piece into quarters. Each quarter will have two sides at right angles, and by inserting the *apex* into the opening of the angle drawn by the pupil, any incorrectness will be detected. A small brass or iron *square* will serve the same purpose, but does not so satisfactorily show that a right angle is equal to a quarter of a circle, which is also called a *quadrant*.

25. *Cross a right line with a perpendicular.* (fig.10.)

The right line should be drawn in various directions, to show the pupil that a perpendicular may be raised on any right line, whether horizontal or oblique.

26. *Draw a rectangular, or right angled triangle,* (figs. 12 and 13.)

This is a triangle of which one of the angles is a right angle, as the lower left hand one in fig. 12, and the top one in fig. 13. The base may be horizontal or inclined.

27. *Make a rectangular isoceles triangle.*

There is no difference between this and figures 12 and 13, except that in an isoceles triangle, two of the sides must be of equal length. In fact, fig. 12 is an isoceles.

Figure 13, though rectangular, is a scalene also.

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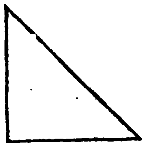

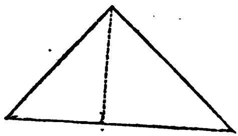

(13)

28. *Draw a rectangle.* (fig. 14.)

A *rectangle* is properly a figure with four sides, of which each two opposite sides are equal and parallel, and of which *all* the angles are right angles.

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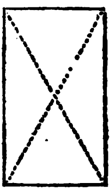
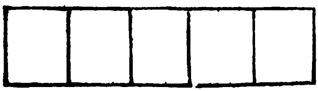




(15)

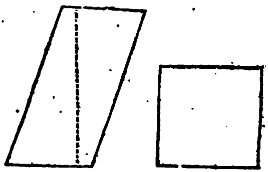
The lower side is the *base*, and the right or left side is the *height*.

To ascertain its correctness, the Monitor may examine every angle with his *quadrant* of pasteboard, or he may with his dividers see if the left hand upper, and

right hand lower angles are as far apart as the other two angles are. Figure 14 is what is often called a *long* or *oblong square.*

29. *Make a rectangle, and cut it into equal right angles.* (fig. 15.)

(16)



(17)

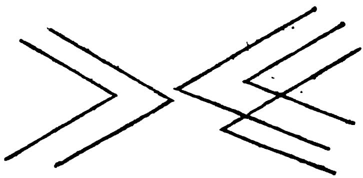
30. *Make a parallelogram, and mark its height.* (fig. 16.)

The *parallelogram,* like the rectangle, has its opposite sides parallel, but none of its angles are *right.* The *height* is a perpendicular dropped from the top to the base, and is marked by the dotted line in the figure.

31. *Make a square.* (fig. 17.)

This figure has its four sides equal, and all its angles *right.*

(18)



(19)

32. *Draw two angles with parallel sides.* (figs. 18 and 19.)

Two angles, as in fig. 18, are called parallel, not because their sides are of equal length, but because their openings and points correspond exactly. Fig. 19 is designed to exercise the pupil in making parallel angles in various positions.

33. *Draw obliques equidistant* (that is, *equally distant) from a perpendicular.*

Draw first a horizontal, raise a perpendicular on its centre, and then draw a line from the top of the perpendicular to each end of the horizontal. The figure will then be an *isoceles triangle*, as in fig. 11.

34. *Make a scalene triangle.* (fig. 13.)

As it is not difficult to make a triangle of unequal sides, it will be well for the monitor to prescribe the length of one or more of them. Thus, he may say: " Make a scalene triangle, of which the three sides shall 1¼ measure ~~two~~ 1¼ inches, one inch, and a half inch."

35. *Make an equilateral triangle.* (fig. 20.)

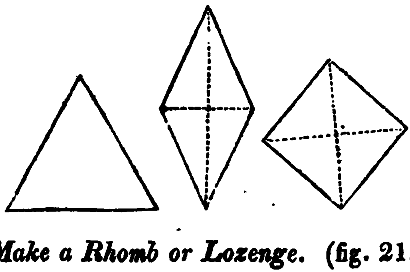
After the pupil makes the figure exactly, let the length of the sides be given, as one, two, three, &c. inches. Then require the point to be under the base, turned to the right, &c.

36. *From a given point draw a perpendicular.*

First draw a right line, then make the proposed point, and lastly draw the perpendicular.

37. *Raise a perpendicular on the end of a right line.*

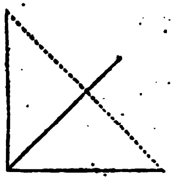
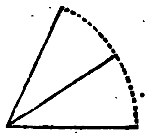
(20) (21) (22)



38. *Make a Rhomb or Lozenge.* (fig. 21.)

The four sides are equal as in the square, but the angles are not *right* angles. To draw this figure, make a right line, cross it with a perpendicular, like the dotted lines in the figure, and then draw the sides.

If the Rhomb or Lozenge have all the angles equal, the figure is merely a square placed obliquely, as in fig. 22.

(23)   (24)

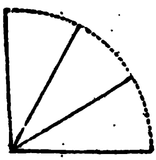
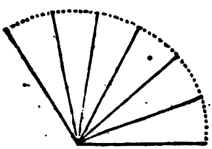
39. *Cut a rectangle into halves.* (fig. 23.)

This will make two angles, whose exactness may be tested by an *eighth* part of a circle of pasteboard, the rectangle being quarter of a circle, as was stated under Prop. 24.

40. *Cut an acute angle into two equal parts.* (fig. 24)

41. *Double an angle.*

Make an angle of any size, and then make another of the same size by the side of it. Suppose the lower angle of fig. 24 to be made first, then by making the upper right line, the angle will be doubled.

(25)   (26)

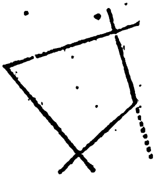
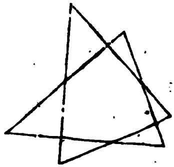
42. *Triple an angle.* (fig. 25.)

43. *Cut an angle into three equal parts.* (fig. 25.)

44. *Cut an angle into six equal parts.* (fig. 26.)

These three propositions need no explanation.

SECOND CLASS.

(1)   (2)

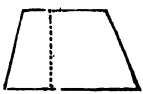
1. *Make two angles of perpendicular sides.*

After having made one angle, the pupil will draw a perpendicular to one of the sides, and then a perpendicular to the other side, until the perpendiculars cross each other.

One of the angles is acute, and the other obtuse; and if you lengthen one of the perpendiculars, a new angle will be formed exactly like the angle first made, as the dotted continuation of the perpendicular in fig. 1 shows.

2. *Make two triangles of perpendicular sides.* (fig.2.)

Make one triangle, and then draw a perpendicular to each side, until the perpendiculars touch and form angles. Each side of each triangle must be perpendicular to some side of the other triangle.

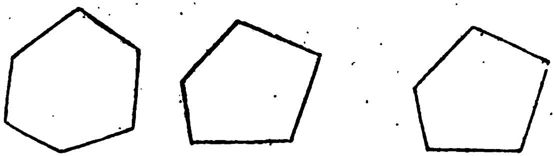
(3) 

trapezoid
when bases are parallel

3. *Make a trapezium.* (fig. 3.)

A Trapezium has four sides, of which, two, called the bases, are parallel. In the figure, these are the upper and lower sides. The height is a perpendicular from base to base. As this figure is easily made, the length of the bases and the height may be given: thus, "Make a trapezium whose height shall be one inch, and whose bases shall be an inch and a half, and two inches."

(4) (5). (6)



4. *Make a six sided polygon of unequal sides.* (fig.4.) The word polygon means many-angled. To make a polygon, the best method is, first to place dots at the angles, and then draw right lines from dot to dot.

5. *Make a five sided polygon of unequal sides.* (fig.5.)

6. *Make two polygons of unequal but parallel sides,* (figs. 5 and 6.)

7. *Make a six sided polygon of equal sides.*

8. *Make a five sided polygon of equal sides.*

A polygon of equal sides is called a *regular polygon.*

9. *From one point of a polygon draw diagonals, and then draw a parallel polygon.* (fig. 7.)

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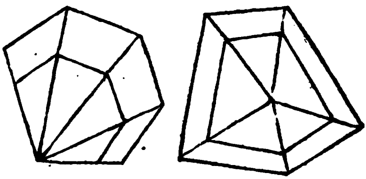


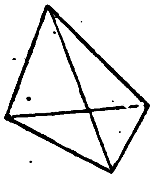
(8)

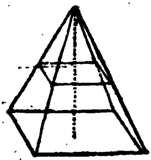
After drawing a polygon, from either of the points carry right lines to all the rest, thus making several triangles. These lines are called *diagonals.* Then you have only to draw parallels to the several sides from diagonal to diagonal.

To vary the exercise, let the pupil draw a polygon *outside* of that first drawn. He will then only have to lengthen the diagonals.

10. *Draw a polygon, and from a central point draw diagonals, then draw a parallel polygon within and outside of the first drawn.* (fig. 8.)

(9)





(10)

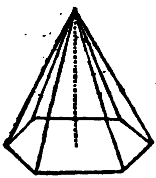
11. *Make a triangular pyramid.* (fig. 9.)

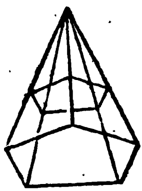
First draw the triangle which forms the base, then place a dot for the point or apex, and draw right lines from the point to each angle of the base.

12. *Draw a quadrangular (or four angled) pyramid,* (fig. 10,) *then cut it by a plane parallel to its base.*

The process is the same as in the preceding figure. The plane, or parallel to the base, must be the last thing done. The *height* of a pyramid is a perpendicular dropped from the apex or summit to the base. The pupil must be careful to distinguish the front lines from the back lines of the figure.

(11)





(12)

13. *Make a six sided pyramid.* (fig. 11.)

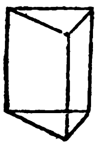
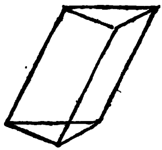
14. *Make a five sided pyramid.* (fig. 12.)

15. *Make a five sided pyramid, and cut it by a plane parallel to the base.* (fig. 12.)

Note. When the base of the pyramid is a regular polygon, and the *height* falls in the centre of it, the pyramid is upright and regular; such are figures 10, 11 and 12.

16. *On two polygons of parallel sides, raise a pyramid.* (fig. 12.)

This is merely another way of performing the last figure, by drawing both polygons before you draw the trunk of the pyramid.

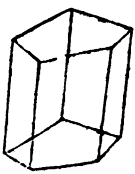
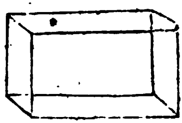
(13)   (14)

17. *Make an upright triangular prism.* (fig. 13.)

A *prism* is a body formed from two equal and parallel polygons, whose corresponding points are joined by lines, all parallel and equal to each other; such are figures 13 to 20 inclusive.

The *height* of a prism is a perpendicular to the two bases. The prism is said to be *upright* when its sides are perpendicular, and oblique when its sides lean or are inclined.

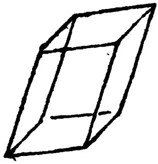
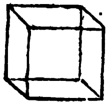
18. *Make an oblique triangular prism.* (fig. 14.)

(15)   (16)

19. *Make an upright five sided prism.* (fig. 15.)

20. *Make an upright parallelopiped.* (fig. 16.)

When the bases of the prism are *parallelograms*, the body is called a parallelopiped. All the six faces are then parallelograms, and the two opposite faces are equal.

(17)   (18)

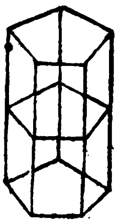
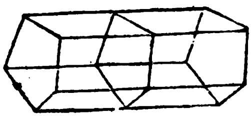
21. *Make an oblique parallelopiped.* (fig. 17.)

22. *Make a Cube.* (fig. 18.)

The cube is a parallelopiped, all of whose faces are equal squares, and each placed at right angles with the contiguous or next squares.

A cube is a *solid square*, but it will be perceived, that in consequence of perspective, only the front and back face appear square. These two faces should be traced first, and the rest will easily be added. Dice are cubes.

23. *Draw an oblique cube.* (fig. 17. making the sides equal.)

(19)   (20)

24. *Cut a prism by a plane parallel to its bases.* (fig. 19.)

A *plane* is a *level*. Place one die upon another, and together they make a prism, cut by a plane where the separation between the dice is.

25. *Make a six sided prism, and double it by lengthening it.* (fig. 19.)

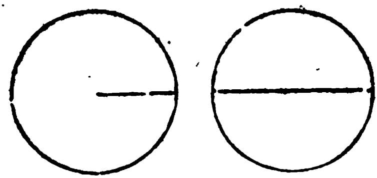
When one die is put upon another, the first die is doubled in length.

26. *Make a five sided prism, and cut it by three planes parallel to its base.*

A long prism may be drawn and cut as in Prop. 24, or a short prism be first made and lengthened as many times as you please.

27. *Draw a five sided prism in a horizontal position.* (fig. 20.) *Cut it by a plane parallel to its base.*

THIRD CLASS.

(1)  (2)

1. *Describe a circle and mark its centre.* (fig. 1.)

By constant practice the pupil will be able to draw a circle, and mark its centre with great exactness. The monitor with a pair of dividers will prove it. The pupils in the Monitorial School have various methods of making circles, without the aid of dividers, the most

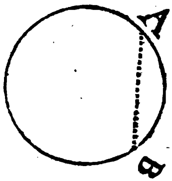
expeditious of which is, holding the pencil between the thumb and fore finger, pressing the nail of the fore finger hard upon the slate or paper, and then turning the slate round. But as this exercises the judgement but little, and the eye still less, it should only be allowed when despatch is required.

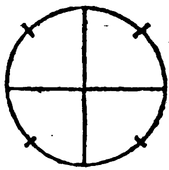
A *radius* is a right line drawn from the centre of a circle to any part of its circumference. (fig. 1.)

A *diameter* of a circle is a right line drawn from one side of the circumference through the centre to the opposite side. (fig. 2.)

An *arc* of a circle is any portion of its circumference. Thus in figure 3, that part of the circumference between

(3)





(4)

A and B is an *arc* and a right line drawn from one end of an *arc* to the other is called a *cord*. In fig. 3, the cord is represented by the dotted line.

The monitor will mark a centre, and draw a radius for the two following questions.

2. *Make a circle round a given centre.* (fig. 1.)

3. *Describe a circle round a given radius.* (fig. 1.)

4. *Cut a circle by two perpendicular diameters.*(fig.4.)

5. *Cut a circle into eight equal parts.* (fig. 4.)

To do this, cut the circle into four parts, as in propsition 5, and then halve the quarters.

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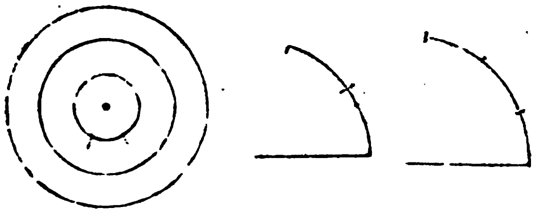


6. *Describe three concentrick circles.* (fig. 5.)

In fig. 5, all the circles have the same centre.

7. *Describe three concentrick circles equidistant from each other.*

8. *Draw two concentrick circles, the diameter of one being three times that of the other.*

9. *Draw an arc of a circle, and mark its centre with a dot.*

The centre of an arc, is the centre of the circle of which the arc is a part.

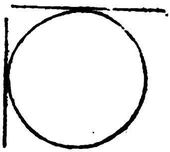
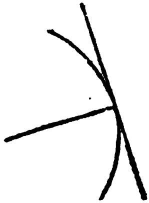
10. *Draw an arc of a given radius.* (fig. 6.)

It is easier to describe a whole circle than merely an arc of it. By placing the dividers on the centre, the monitor will easily test the correctness of the arc.

11. *Cut an arc into two equal parts.* (fig. 6.)

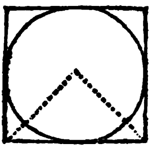
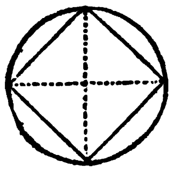
12. *Cut an arc into three equal parts.* (fig. 7.)

13. *Cut an arc into three smaller ones, and draw the cord of each.*

(8)   (9)

14. *Describe a circle, and draw a tangent to it.* (fig. 8.)

Tangent comes from a latin word, which means to *touch*. A *tangent* is a right line which touches a circle, but does not cut any of it off. If a right line be drawn from the centre of the circle or arc to the *point of contact* (that is, the point where the tangent touches the circle) the two right lines, (that is, the radius and the tangent) will be perpendicular to each other. (fig. 9.) The monitor may test this with his quadrant of pasteboard; or, marking two places on the tangent at equal distances from the *point of contact*, he may see with his dividers if these points are at equal distances from the centre.

(10)   (11)

15. *Draw four tangents to a circle, forming a quadrilateral or four sided figure.*

This figure need not form a perfect square, as in figure 10.

16. *Circumscribe or surround a circle with a square.* (fig. 10.)

When the four tangents make right angles with each other, the figure is a square. In other cases, any direction may be given to *two* of the tangents.

In figure 10, we say the circle is *circumscribed* by the square, or the circle *inscribed* in a square.

17. *Inscribe a square in a circle.* (fig. 11.)

When a polygon has all the points of its angles touching a circle, it is said to be *inscribed* in a circle, and the circle *circumscribes* the polygon.

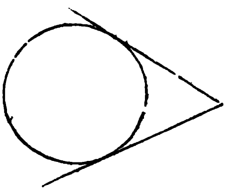
18. *Double an arc of a circle.* (fig. 6.)

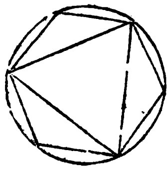
This is more difficult than Prop. 11. First draw an arc and mark its centre, then prolong the arc to two, three, &c. times its former size.

19. *Draw a tangent to a circle from a given point outside.* (fig. 8.)

20. *Draw two tangents to a circle from a given point.* (fig. 12.)

(12)





(13)

Observe that in drawing a tangent to a circle in problem 14, any part of the circle may be taken, but when a tangent is drawn from a given point, it can hit but two points as in fig. 12.

21. *Cut a circle into six equal parts*, (or, in other words, inscribe a regular hexagon in a circle.) (fig. 13.)

The radius of any circle is equal to one side of the hexagon to be inscribed in it. The monitor, therefore,

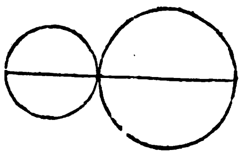
may measure the radius with his dividers, and then apply them to each side of the hexagon. In other words, the *cord* of an arc, which is the sixth part of a circle, is equal to a radius or half diameter, (usually called a *semi-diameter*.)

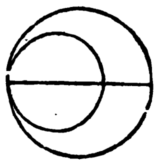
22. *Cut a circle into three equal parts, and inscribe an equilateral triangle.* (fig. 13.)

After the hexagon is correctly drawn by problem 21st, it is easy to inscribe the triangle required in this, by drawing a cord between two points of the hexagon.

If cords be then drawn between the three remaining points of the hexagon, another triangle will be formed, whose base will be opposite the base of the other triangle, forming a beautiful figure resembling a star.

(14)





(15)

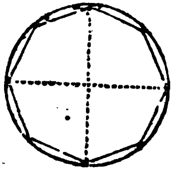
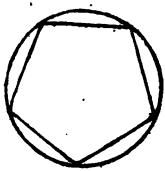
23. *Make two unequal circles tangent outside.* (fig. 14.)

Unequal circles are circles of unequal size only.

24. *Make two unequal circles tangent inside.* (fig. 15.)

25. *The centres and the point of contact being given, perform problems 23 and 24.*

The monitor will mark the centres, &c. When the circles touch either within or without, the point of contact and the two centres will be in a right line, and these may be tested with a rule.

(16)   (17)

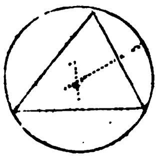
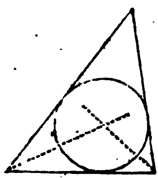
A *regular polygon* has all its sides equal, and all its angles of an equal opening. When such a polygon is inscribed in a circle, the sides are cords of equal arcs, and the points cut the circle into equal parts.

26. *Inscribe a regular octagon in a circle.* (fig.16.)

Draw two diameters perpendicular to each other, then divide each quarter of the circle into halves by other diameters; then draw arcs from diameter to diameter.

27. *Inscribe a regular pentagon in a circle.* (fig. 17.)

It is difficult by the eye alone to divide the circumference into five equal parts, and the object of this problem is to exercise the pupils.

(18)   (19)

28. *Make a triangle, and circumscribe a circle,* (fig. 18.)

First make a triangle, and then the object is to describe a circle which shall cut each of its three points. To do this, raise a perpendicular on the middle of one

of the sides, and then raise another on another side. These perpendiculars will cross each other, and *the point of section* (that is, the point where they cut each other) will be the centre of the circle required.

In the figure, the dotted lines show the perpendiculars and centre.

29. *Make a circle, and draw a tangent triangle.* (fig. 19.)

Three tangents to a circle are easily made, but the monitor may increase the difficulty by giving directions to the tangent sides. Thus, let two sides be at right angles, obtuse or acute; let the triangle be equilateral, &c.

30. *Draw a regular pentagon, and circumscribe it with a circle.* (fig. 17.)

31. *Draw a regular hexagon, and circumscribe it with a circle.* (fig. 13.)

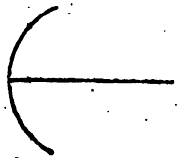
32. *Draw a regular octagon, and circumscribe it with a circle.* (fig. 16.)

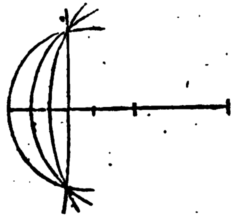
In the former problems, the circle was made first, now the polygon.

33. *Inscribe a circle in a triangle.* (fig. 19.)

To find the centre of the circle, draw a line from the middle of either side of the triangle to the point opposite, then do the same by another side and its opposite point; the place where these two lines cross each other, will be the centre of the circle to be inscribed. See the dotted lines in fig. 19.

34. *Make an arc which shall pass through two given points.* (fig. 20.)

(20) 

 (21)

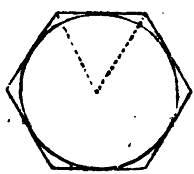
After having marked two points, trace an arc of a circle which shall pass through both of them. The centre must be somewhere on a perpendicular to the middle of a cord which would join these two points.

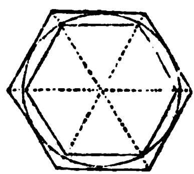
35. *Make several arcs pass through two given points.* (fig. 21.)

Draw one arc as in problem 34, then a cord from point to point, then a perpendicular to the cord, and then you may make any number of arcs pass through the two points, all of whose centres must be on the perpendicular.

This problem will assist the pupil in drawing the meridians on a map of the globe.

36. *Describe a circle, and circumscribe it with a hexagon.* (fig. 22.)

(22) 

 (23)

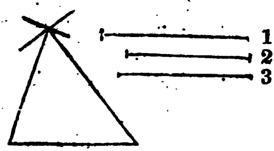
Cut the circumference into six equal arcs, as if you wished to inscribe the polygon. Then draw a radius to each point, and six tangents perpendicular to the radii will form the regular polygon required.

37. *Inscribe and circumscribe a circle with regular and parallel hexagons.* (fig. 23.)

38. *Inscribe a circle in a regular hexagon.* (fig. 22.) This problem is the inverse of the 36th. First draw the hexagon, then describe the circle, touching it on all sides. The centre of the circle may be found by raising perpendiculars on the middle of any two sides until they cross each other. The point where they cross, is the centre.

39. *Make a triangle whose three sides are given.* (fig. 24.)

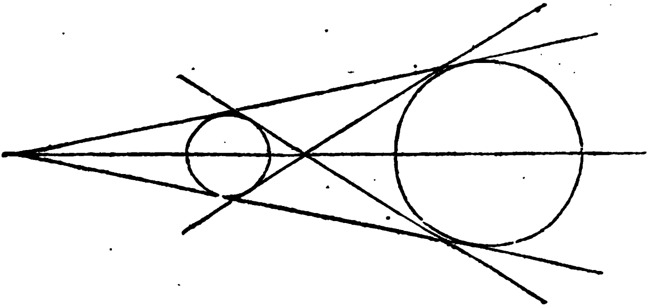
(24)



Trace three right lines for sides. Take one of them, the longest if you please, for the base, and then make a point where you think the other two sides will reach. The difficulty is to ascertain exactly where this point should be. With dividers it may be easily found in the following manner. After you have drawn the base, open the dividers the length of the next side to be drawn, and placing one foot of the dividers on one end of the base, draw an arc with the other foot. Then taking the length of the third side, place one foot on the other end of the base, and draw an arc which shall cross the former arc: the point where the arcs cross each other is the summit or apex required.

If the two arcs cannot cross, the problem is said to be *absurd:* for no triangle can be made of the given sides. Each of the three sides must be shorter than the two others would be if united.

(1) FOURTH CLASS.



1. *Draw a right line tangent to two circles.* (fig. 1.)

Take either of the right lines in fig. 1. The circles may be placed more or less distant from each other, and may even *intersect* or cut each other. A radius drawn from the centre to *the point of contact* will be perpendicular to the tangent.

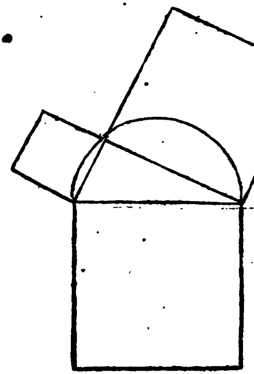
2. *Draw four tangents to two circles.* (fig. 1.)

There may be two interiour and two exteriour tangents. The right line which joins the centres is also the point where the tangents must *intersect* each other.

3. *Add two squares.* (fig. 2.)

This figure and figure 3, present two rectangular triangles, on whose sides three squares are constructed. The two small squares have this peculiarity, that one of their sides is exactly one side of the triangle, and another is merely a prolongation of the other side of the right angle. If a semicircle be drawn on the greatest side of the triangle it must touch the apex of the triangle.

It is a fact in geometry, that the greatest of these three squares, contains a surface equal to the other two added together.



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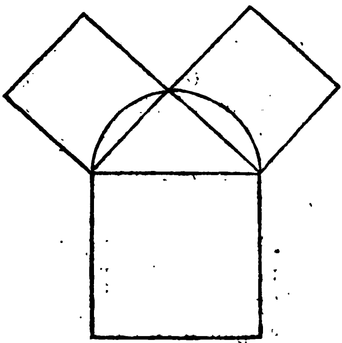
4. *Add two given squares.*

Make a right angle, and on its sides place the sides of the squares. These lengths will be the small sides of your right angled triangle; then draw the longest side, and you have the side of a square equal to the other two.



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5. *Double a square.* (fig. 3.)

The triangle must be a rectangular isoceles, and the two small squares will then be equal to each other, or united they will be equal to the large square.

6. *Cut off a square.* (fig. 2.)

If the great square and one of the small ones be given, it is easy to find the size of the other.

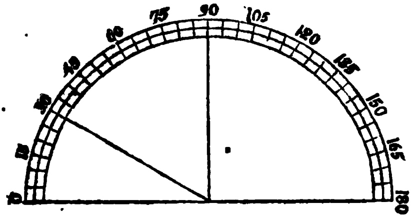
First draw the great side, then the semicircle, then draw from either end of the great side, (which you will notice is the diameter of the semicircle) a cord of the semicircle, which is equal to a side of the given small square. The other cord which will finish the right angled triangle, is the side of the square required.

7. *Take the half of a square.* (fig. 3.)

A perpendicular to the middle of the long side, will strike the semi-circle, and a cord from this point of intersection to either end of the diameter or long side, will give the side of a square, half as large as the great square.

8. *Make a graduated semicircle, usually called a Protracter.* (fig. 4.)

(4).



By general consent a circle is divided into 360 equal parts, called degrees. A semicircle of course contains 180 degrees, that is, half of 360.

After having drawn a semicircle and its diameter, draw a perpendicular radius. This radius forms a right angle with the diameter, and cutting the semicircle in two equal parts or quarters of circles, leaves 90 degrees for each of them. If 90 degrees of a circle make a right angle, 45 degrees will make half a right angle, &c.

Or by another method. A radius, if made a cord of the semicircle, will allow three cords, each of which will contain 60 degrees; halve these arcs, and you have arcs of 30 degrees; halve the arcs of 30 degrees, and you have 15 degrees; cut these into three equal parts, and you have 5 degrees; then divide the arcs of five degrees into five parts, and you have the 180 degrees of the semicircle.

Whether the circle be large or small, it is divided into the same number of degrees; for if the radii of a small circle be lengthened out, and a larger circle drawn from the same centre, the radii will form the same part of the large as of the small circle, and the angle between any two radii will be unchanged.

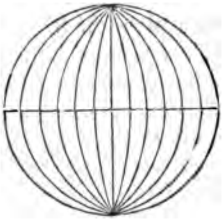
9. *Make an angle of* 30 *degrees on the graduated semicircle.* (fig. 4.)

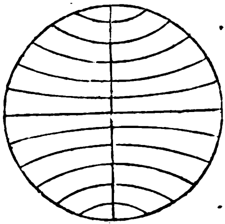
A radius drawn from the centre to the number 30 on the graduated semicircle, will form an angle of 30 degrees with the diameter of the semicircle. And so for any other number of degrees. It will be seen that any number of degrees less than 90 will make an acute angle, and more than 90 degrees will form an obtuse angle: thus, in fig. 4, 30 degrees form an acute angle, and the remaining 150 degrees of the half circle form an obtuse angle.

Angles, therefore, are measured by their openings. Place the point of any angle on the centre of the semicircle, or the centre of the semicircle on the point of the angle, and then by seeing how many degrees the opening of the angle measures on the graduated edge of the semicircle, you will find the size of the angle. If the sides of the angle do not extend to the circumference, you may extend them till they do. If they extend beyond the circumference, measure the angle where the graduated circle cuts its sides.

10. After the pupil has drawn the semicircle, the monitor must require him to draw angles of various sizes, from 1 to 180 degrees. Then, laying aside the semicircle, let him draw angles of various degrees, which the monitor will test by his brass semicircle, or by angles of pasteboard previously prepared: the latter are the handiest if well cut.

11. *Make a sphere and its meridians.* (fig. 5.)

(5) 

 (6)

Describe a circle, and draw two diameters perpendicular to each other; one for the *axis*, and the other for the *equator*, (a circle which goes round the earth at an equal distance from the ends of the *axis*, which ends are called *poles*). Then draw arcs of a circle, all passing through the poles, and whose centres are consequently on the perpendicular to the axis (that is, the equator) prolonged to the right or left hand. See Class III, problem 35. fig. 21.

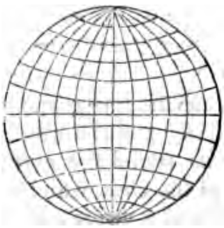
These arcs have their centre as much farther off as they are nearer the axis. Their number is not important, but if five be made on each side of the axis, as in the figure, each of the spaces between them will be just 15 degrees, or one twenty-fourth part of the whole sphere. These arcs in geography are called *meridians*.

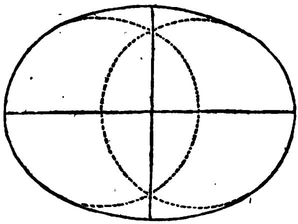
12. *Make a sphere, and the little circles which run parallel to the equator.* (fig. 7.)

After having described a circle, and its two perpendicular diameters, as in the preceding problem, divide the circle by dots into arcs of say 15 degrees; there will then be five dots and six arcs between the equator and each pole; then divide the axis into the same number of parts. The next object is to draw an arc through the three points nearest the equator, then through the three next, and so on till all are drawn.

These arcs on a solid globe would be parallel to the equator, but do not appear so on a plane or flat surface. In geography, they are called *Parallels of Latitude.*

If an apple be taken and sliced from side to side, it will exactly represent these circles, which are planes cutting a sphere perpendicular to its axis.

(7) 

 (8)

13. *Draw a sphere which shall unite the two preceding problems.* (fig. 7.)

14. *Draw an ellipse.* (fig. 8.)

An ellipse is an oval, which may be more or less lengthened, as in figures 9 to 13. To make an ellipse: first cross two perpendicular right lines; the upper and lower halves to be of equal length, and the right and left hand to be equal also. You thus obtain the longest and shortest diameter of the ellipse, called its great and small axis. The next thing is to draw the curved lines as in

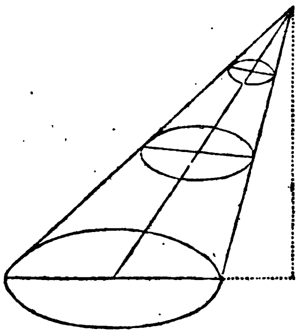
the figure. The length of the diameters may be varied at pleasure by the monitor.

There are various geometrical rules for drawing ellipses, but it is not within the scope of our work to notice more than one of the simplest forms of ovals. Draw a circle and mark its centre and diameter. Then on one end of the diameter, draw another circle of the same size intersecting the former. Then opening the dividers the length of the diameter, place one foot on the lower point of intersection, and connect the two circles at top, and then do the same by the other point of intersection and the bottom part of the oval.

A simple and amusing method is, to stick two pins into a piece of paper firmly, at any distance from each other; tie the ends of a piece of string together, and put the string round both pins. Hold a pencil then at any part of the string, and move it round; an ellipse will be formed, of which the two pins will be the two *foci* or centres. By lengthening or shortening the string, the figure may be made more or less elliptical.

15. *Draw an oblique cone,* (fig. 9.)

(9)



Take a circle for the base, and from some point over this plane or level, draw right lines to the circumference

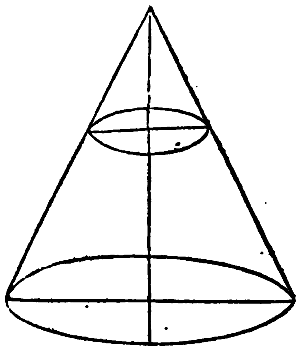
of the circle, and you have a cone. A cone is, in fact, a pyramid whose base is a circle, and not a polygon. Sugar loaves are cones.

The *height* of a cone is a perpendicular let fall from the top or apex to the base. If this perpendicular fall exactly upon the centre of the base, the cone is *upright*.

The perspective by changing the apparent dimensions of bodies, gives to the base of a cone the form of an ellipse. The cone presents no other difficulty than the ellipse.

16. *Draw an upright cone.* (fig. 10.)

(10)



17. *Draw an oblique cone, and cut it by two planes parallel to the base.* (fig. 9.)

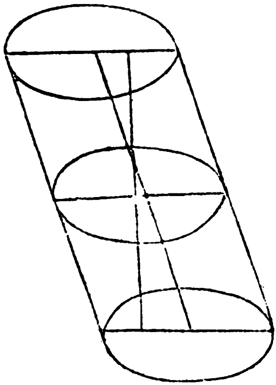
18. *Draw an oblique cylinder.* (fig. 11.)

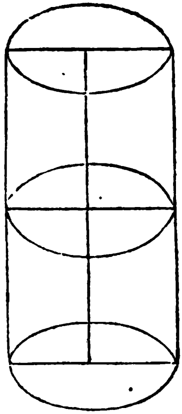
Draw two horizontal lines parallel to each other. Draw two equal circles, of which these shall be diameters. Let a right line go from centre to centre, and it will be the *axis*. Then draw lines from circumference to circumference, and you have a cylinder. A piece of the funnel of a stove is a cylinder. A cylinder is, in fact, a prism whose bases are circles instead of polygons.

The height of a cylinder is the length of the axis, or the distance from one base to the other. If the axis be perpendicular, the cylinder is *upright*.

Here, as in the cone, the laws of perspective change the circles into ellipses. The axes of the ellipses, and that of the cylinder, may be given in inches by the monitor.

(11)





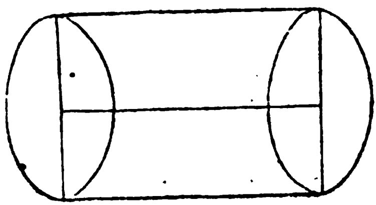
(12)

19. *Draw an upright cylinder.* (fig. 12.)

20. *Cut a cylinder by a section parallel to its base.* (figs. 11 and 12.)

21. *Make a cylinder whose axis shall be horizontal.* (fig. 13.)

(13)



FIFTH CLASS.

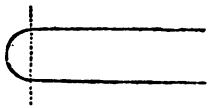
The figures of the Fifth Class are formed by the union of such lines as have already been given, viz. horizontals, perpendiculars, and arcs of circles or ellipses.

1. *Draw a fillet.* (fig. 1.)

2. *Draw a bead.* (fig. 2.)

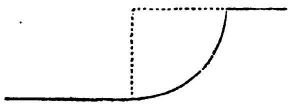
3. *Draw a congee.* (fig. 3.)

(1)



(2)

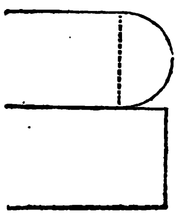
(3)



These *mouldings*, as they are called in architecture, are so simple as to need no explanation. Horizontals and verticals will be found in them, with circles, of which the dotted lines mark the centre.

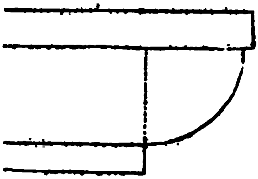
4. *Draw a torus with its plinth.* (fig. 4.)

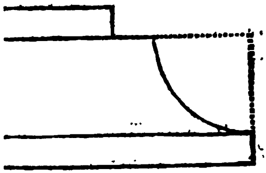
(5)



The torus, of which the profile is here given, is a large moulding, usually placed at the base of columns. The torus has its diameter, vertical, and parallel, to the axis of the column. The plinth, is the short cylinder which supports the torus.

(5) (6)

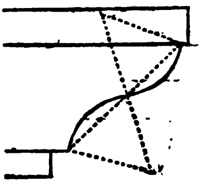


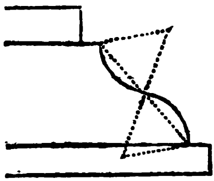


5. *Make a quarter-round with its fillets.* (fig. 5.)

6. *Make a quarter-round reversed, with its fillets.* (fig. 6.)

(7)





(8)

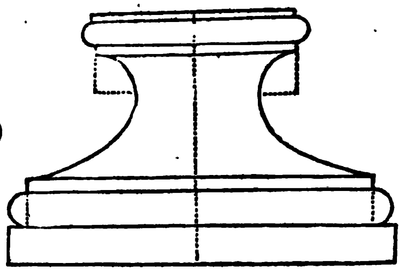
7. *Make an ogee or talon with its fillets.* (fig. 7.)

8. *Make an ogee or talon with its fillets reversed.* (fig. 8.)

The profile of the talon is formed by two arcs of a circle united at their end, and whose centres are on different sides of a right line which joins their extremities. This line, which is dotted in the figure, is cut in the middle by the arcs, and each half being taken for the base of an equilateral triangle, the summit or apex of the triangle is the centre of the arc. The right line which joins these two summits or centres of the arcs, passes through the point where the two arcs touch at the middle of the first right line.

9. *The monitor must now require the pupil to draw the eight preceding figures, turned towards the left.*

(9)



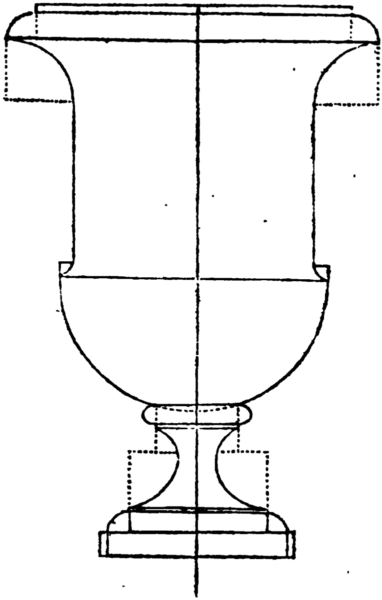
10. *Make a pedestal.* (fig. 9.)

Here the arcs, end to end, belong one to an ellipse, and the other to a circle. The centres and axes are marked.

11. *Make a vase or flower pot.* (fig. 10.)

It will be recollected that this and the preceding figures of this Class, are *flat* representations of *round* objects.

(10)



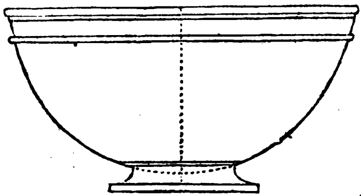
12. *Make a ewer and basin.* (fig. 11.)

Here is a half ellipse joined to two quarter-circles. In the foot of the ewer, its handle and neck, the curves are fanciful. In this, and in all the following figures, the drawings represent *round* bodies.

(11)

13. *Draw a bowl.* (fig. 12.)

Here is a semicircle ornamented with parallel fillets, and placed on a low pedestal.

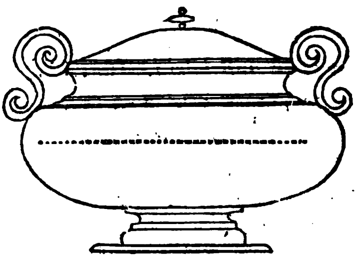


(12)

14. *Draw a soup dish or turenne.* (fig. 13.)

The body is formed of a half ellipse, surmounted by a fancy curve.

(13)



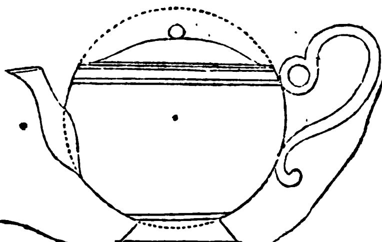
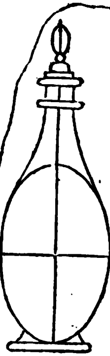
~~15. *Make a vase with a fountain.* (fig. 14.)~~

~~A sort of column supports a vessel formed of a talon or ogee. (fig. 8.) A sphere supports the jet, through which the liquid passes.~~

Omit & raise the Teapot

15. *Draw a tea pot.* (fig. 14.)

The principal part is a circle, the handle and nose fanciful.

(14)   (15)

16. *Draw a decanter.* (fig. 15.)

The body is formed of an ellipse truncated (that is, cut off) at the two ends.

Put the decanter below this

The pupils should here be required to exercise their ingenuity and taste in drawing similar figures, without copies, or by having real objects placed before them, such as books in various positions, articles of furniture, &c. &c.

It is left to the Instructer's judgement, whether to take the Sixth Class or the Geometrical Arithmetick next. But before attempting either, the student should have gone over all the preceding classes several times on the slate, then with a lead pencil on paper, and lastly, with a pen and ink. Very young children may draw all the preceding figures, but it requires some maturity to draw those of the sixth class, and to apply the arithmetick.

SIXTH CLASS.

By the number and complication of details in the figures of this Class, it is evident that they are calculated only for practised pupils, who are skilful in drawing the figures of the five preceding classes, as well with the rule and dividers as without them.

At first the pupils should not draw the details of the frieze, capitals, &c. but merely the large and more important parts, giving them their just proportions, upon which their graceful appearance depends.

There are four modes of arranging the parts of a building, commonly called the four Orders of Architecture, viz. the Tuscan, Dorick, Ionick and Corinthian Orders.

Each has three principal parts, the Column, the Entablature which surmounts it, and the pedestal which supports it. The pedestal is often omitted, and its place supplied by a plinth only. The order is then reduced to two parts only. Indeed, sometimes the

edifice has no columns, but still it is said to belong to some order, because certain proportions are observed in its parts.

The *Corinthian Order* is distinguished by the richness of the sculptures which decorate its frieze, and which are infinitely varied. The capital of the column is also furnished with two rows of leaves, and eight volutes.

The *Ionick Order* is distinguished by the volutes of its capital.

The *Dorick Order* has its frieze ornamented with triglyps and metopes.

The *Tuscan*, the most plain and solid of all the orders, allows no ornament.

Besides these characteristicks, the different orders are also distinguished by the proportions which regulate their parts, as will be shown hereafter.

Nothing is said here of a fifth order called the *Composite*, because it is composed of the Ionick and Corinthian; nor is mention made of the Gothick, Attick, German, and Arabick, for a complete treatise on architecture is not intended.

By comparing the different monuments which artists have thought worthy to be considered models, on account of the taste they exhibit, proportions have been noticed in the parts, which have become rules for imitation. Not that there exist in fact, exact and rigorous proportions and rules which are never deviated from, for art has not those fixed rules which are found in the sciences. Certain proportions having been ordinarily observed, and by the consent of all persons of good taste, being found the most suitable, these proportions should be considered as a rule not to be deviated from

without good reasons. The draughtsman by strictly observing these proportions, is secured from criticism, is sure of doing well, and of obtaining the approbation of judges.

The following are the proportions thus settled:

In *all* the orders, the *entablature* is one quarter as high as the *column*, and the *pedestal* a third.

Each of these three parts is subdivided into three others, viz.

The PEDESTAL into the *Cornice*, *Dye* and *Base*.

The COLUMN into the *Base*, *Shaft and Capital*.

The ENTABLATURE into the *Architrave*, *Frieze*, and *Cornice*.

Care must be taken to proportion the size of the column to its order, its own height, and the height of the edifice it is to ornament.

The height of the Tuscan Column, including its base and capital, is seven times its diameter; of the Dorick, eight times; of the Ionick, nine times; and of the Corinthian, ten times.

The subdivisions are also regulated by this scale. A *radius*, or half diameter of a column, is called a *Module*, which, when once ascertained, determines the height of the frieze, cornice, shaft, &c. These modules are each divided into twelve equal parts in the Tuscan and Dorick orders, and into eighteen in the Ionick and Corinthian.

The number of Modules or half diameters which the subdivisions of each order measure, is as follows.

TUSCAN ORDER.

COLUMN........................14 Modules.

Base	1	14
Shaft	12	
Capital	1	

ENTABLATURE................$3\frac{1}{2}$ Modules.

Architrave	1	$3\frac{1}{2}$
Frieze	$1\frac{1}{6}$	
Cornice	$1\frac{1}{3}$	

PEDESTAL.....................$4\frac{2}{3}$ Modules.

Cornice	$\frac{1}{2}$	$4\frac{2}{3}$
Dye	$3\frac{2}{3}$	
Base	$\frac{1}{2}$	

In all, 22 Modules and $\frac{1}{6}$, and without the Pedestal, $17\frac{1}{2}$.

The *Intercolumniation*, or space between the bases of two columns, is $4\frac{2}{3}$ Modules.

DORICK ORDER.

COLUMN..........................16 Modules.

Base	1	16
Shaft	14	
Capital	1	

ENTABLATURE................4 Modules.

Architrave	1	4
Frieze	$1\frac{1}{2}$	
Cornice	$1\frac{1}{2}$	

PEDESTAL......................$5\frac{1}{3}$ Modules.

Cornice	$\frac{1}{2}$	$5\frac{1}{3}$
Dye	4	
Base	$\frac{5}{6}$	

In all, $25\frac{1}{3}$ Modules, and without the Pedestal, 20 Modules.

The intercolumniation is $5\frac{1}{2}$ Modules.

IONICK ORDER.

COLUMN.............................18 Modules.

Base	1	18
Shaft	$16\frac{1}{3}$	
Capital	$\frac{2}{3}$	

ENTABLATURE................$4\frac{1}{2}$ Modules.

Architrave	$1\frac{1}{4}$	$4\frac{1}{2}$
Frieze	$1\frac{1}{2}$	
Cornice	$1\frac{3}{4}$	

PEDESTAL...........................6 Modules.

Cornice	$\frac{1}{2}$	6
Dye	5	
Base	$\frac{1}{2}$	

In all, $28\frac{1}{2}$ Modules, and without Pedestal, $22\frac{1}{2}$.
The intercolumniation is $4\frac{1}{2}$ Modules.

CORINTHIAN ORDER.

COLUMN..........................20 Modules.

Base	1	20
Shaft	$16\frac{2}{3}$	
Capital	$2\frac{1}{3}$	

ENTABLATURE.................5 Modules.

Arçhitrave	$1\frac{1}{2}$	5
Frieze	$1\frac{1}{2}$	
Cornice	2	

PEDESTAL......................$6\frac{2}{3}$ Modules.

Cornice		14 parts of a Mod.	$6\frac{2}{3}$
Dye	5 Mod.	4 " " "	
Base	$\frac{2}{3}$ "		

In all, $31\frac{2}{3}$ Modules, or, without Pedestal, 25.
The intercolumniation is $4\frac{2}{3}$ Modules.

Thus to raise an order of a given height, divide the height, as expressed in feet or inches, by the number of modules belonging to the order, and the quotient will be the module or semidiameter of the base of the column. We say the *base*, because it is found that the column is more graceful if it insensibly diminishes towards the top, so as to lose one third of a module in the two upper thirds of the column.

The module being thus ascertained, is divided into smaller parts, and thus gives the height of all the subdivisions.

A vertical or perpendicular is drawn, on which are successively marked the lengths of the cornice, the frieze, the architrave, &c. On these points, horizontals are drawn, between which will be contained all the mouldings of the order.

Or—if the circumference of the base of a column be measured with a string, and multiplied by 0,159, the module will be found; and from this, the height of the whole edifice, and of all its parts.

Pediments are triangular structures, whose height may be much varied according to their extent. There are some whose height is a third, fourth, fifth or sixth of the base. This proportion is left to the taste of the artist; and it is pretty much so with the various mouldings which compose the cornices, capitals, &c.

Pilasters are square columns (parallelopipeds) seldom detached, but fastened to the wall or wainscot, and projecting nearly a third or fourth of a module. In other respects, their ornaments, capitals, base, and all their proportions are regulated by the rules of the order they belong to.

THE cuts of the three first classes are copied from the French original; those of the fourth and fifth classes, from drawings by pupils of the Monitorial School. The copperplate was designed by the translator. For the purpose of exhibiting the four principal orders, and affording an opportunity of comparing their relative height, grace, and strength, the *module* of each order is the same, viz. three twentieths of an inch.

PROBLEMS

IN

Arithmetick and Geometry.

It is easy to unite two branches of instruction, which are so important and so analagous. Artists and mechanicks ought to be able themselves to measure their work, whatever it may be; and to draw plans, to make contracts for work, to calculate the price, and quantity of materials necessary for the work; and in fine, to make all the estimates required by the art they practise.

To enable them to do this, we shall unite the elements of Geometry and Arithmetick, explain the problems and rules of most common occurrence, and add numerical examples to illustrate their application. The master will vary the examples at pleasure.

Inches are divided into tenths, hundredths, thousandths, &c. and calling the inch unity, or a whole, we place a comma at the right hand of it to separate the fractions or parts. For example, to express 8 inches and 6 tenths, we write 8,6; for 9 inches and 72 hundredths, we write 9,72; for 10 inches and 626 thousandths, we write 10,626, and so on. If there be no whole inches, a cipher is put in the place of inches, and the comma as before, thus, 0,382 stands for 382 thousandths of an inch, or as the first column at the right of

the comma is tenths, the second hundredths, and the third thousandths, we may read it, 3 tenths, 8 hundredths, and two thousandths of an inch; but the former way is preferable.*

In ADDITION and SUBTRACTION, columns of the same name should be placed under each other, and the calculation made as if there were no decimal fractions. The following examples will show the use of this rule.

Addition.	*Subtraction.*	
432,178	324,15	30,4
17,231	187,3	19,28
9,4	———	———
83,502	136,85	11,12
7,08		
———		
549,391		

Add the following sums:

36,075	8,1	4,44
9,6	28,04	8,176
345,56	686,008	0,43
86,115	5,16	10,08
6,8	82,686	2,5
———	———	———
———	———	———

Subtract the following:

68,06	4,85	15,908
17,67	3,9	12,819
———	———	———
———	———	———

The master or monitor may vary such sums at pleasure.

* After thousandths, come ten thousandths, hundred thousandths, millionths, &c. but for ordinary uses we seldom come down to so small a fraction.

MULTIPLICATION is performed as if there were no comma; but in the sum total, as many figures must be cut off at the right hand of the comma, as are cut off in both the multiplier and sum multiplied. For example:

4,37	183,2
2,3	0,24
1311	7328
874	3664
10,051	43,968

Multiply	37,04	by	4,8
	3,96	by	0,84
	18,5	by	5,18
	468,007	by	8,14

In DIVISION, add ciphers at the right of whichever of the two numbers has the least number of decimal figures, that the *dividend* or sum to be divided, and the *divisor* or sum to divide by, may have an equal number of them; then pay no regard to the comma, and divide as in ordinary arithmetick.

When you have found the wholes of the quotient, place a comma after them, and then find the decimals by putting a cipher at the right of the remainder, and dividing anew, you will then have the first figure after the comma in the quotient. Add another cipher to the remainder, and you will have another decimal figure, and so on.

EXAMPLES.

To divide 10,051 by 4,37 I write thus:

```
4370) 10051 (2,3
       8740
      ------
       13110
       13110
      ------
           0
```

That is, I add a cipher to 4,37 thousandths, to make them 10 thousandths, because there are 10 thousandths in the dividend. 10 thousandths divided by 10 thousandths, will give 10 thousandths for the quotient; hundredths divided by hundredths, give hundredths, &c.

In the above sum, the answer is, 2 ten thousandths and 3 tenths of a ten thousandth.

Again, divide 154,3 by 21,26.

```
21,26) 15430 (7,25
       14882
       -----
         5480
         4252
         -----
         12280
         10630
         -----
          1650 remainder.
```

The answer is 7 hundredths, and 25 hundredths of a hundred. It is unnecessary to carry the remainder to any lower fraction.

Divide	36,75	by	8,4
	460,8	by	46,54
	84,968	by	8,68
	166,14	by	19,762
	86,4	by	4,86

When you have obtained two or three decimal figures in the quotient, it is useless to carry the calculation any further, as they will be too small.

We shall now endeavour to apply these principles.

PART I.

OF LINES.

Problem I. *To find a side of a rectangular triangle, the two others being known.*

Rule. Multiply by itself each of the known sides, then add them together if you wish to find the greater side; and subtract the lesser number from the greater if you wish to find one of the lesser sides. Then you will have the same result as if you had multiplied the unknown side by itself. Of course, you have only to find what number multiplied by itself, will give this result.

Example 1. The smaller sides of a rectangular triangle, (figs. 12 and 13) are one 3, and the other 4 inches, find the larger side. Class I.

3	times	3	are	9
4	times	4	are	16
			These added make	25

5 multiplied by itself makes 25, and the greater side or side required, must be 5 inches.

Example 2. In a rectangle, (1st Class, fig. 14,) it is known that the base is 8 inches, 54 hundredths, the

height is unknown, but the diagonal (a right line drawn from corner to corner) is found by measurement to be 15 inches, 32 hundredths. What is the height?

Note. A diagonal cuts the *oblong square* or rectangle into two rectangular triangles, of which the height above required is one of the smaller sides.

```
  8,54        15,32
  8,54        15,32
  ----        -----
  3416         3064
 4270         4596
6832         7660
------      1532
72,9316     --------
            234,7024
```

As a smaller side is required, subtract the known smaller from the larger.

```
234,7024
 72,9316
--------
161,7708
```

It remains to find a number, which multiplied by itself will give 161,770. A few trials will show that this is (as near as possible) 12,719 as may be found by multiplying this number by itself. The height then, is 12 inches, and 719 thousandths of an inch.

Example 3. Find the height of an isoceles triangle, (1st *Class*, *Prob*. 27.) whose base is ,52 and the equal sides, ,87. The perpendicular drawn from the summit, cuts the base in halves, and is a small side of a rectangular triangle, of which

the base is half the larger one, or . . . ,26

The great side of the new angle, which was one of the equal sides of the isoceles, is . . . . ,87

```
                          ,26
                          ,26
                          ---
                ,87       156
                ,87       52
                ---       ---
From  7569      609       676
Take   676     696
      ----     ----
      6893     7569
```

A few trials will show, that the height required is, 83 nearly, for 83 times 83 are 6889.

4. The smaller sides of a rectangular scalene triangle, (1st Class, fig. 13,) are 5 and 7 inches, required the larger side. Ans? 8 in., 6 in nearly.

5. One small side of a rectangular scalene triangle is, $8^{in.},3$ and the other $4^{in.},8$ what is the size of the third side? Ans? 9, 59 in. nearly.

6. The two equal sides of a rectangular isoceles triangle, are 4,8 in length, what is the length of the base? 6,785 in nearly

7. The base of a rectangle (Ex. 2) is 7,15 ; the diagonal 13,25 ; required the height (that is, the third side of the triangle.) Ans. 14,14 in. nearly.

8. The base of a rectangle is 4,75 and the height 7,25 required the diagonal, or longest side of the triangle. Ans. 8,67 in. nearly.

9. What is the height of an isoceles triangle, of which the base is 6 inches, and the equal sides $3^{in.},8$ each? Ans. 2,33 in. nearly.

The instructer may increase these examples at pleasure.

Problem II. *To find the circumference of a circle when lengthened out into a right line.*

Rule. Multiply its diameter by 3, and add a seventh of a diameter.

Example 1. The diameter of a circle is $4^{in.},523$.

	4,523
	3
	13,569
A seventh of 4,523 is	,646
The circumference is	14,215

2. The width of a basin is $5^{in.},5$ how long must a string be to reach round it?

	5,5	
	3	
	16,5	
A seventh of 5,5 . .	0,786	
Length of string, . .	17,286	the circumference.

3. The diameter of a circle is 4,45 what is the circumference? *Ans. 13,98 in.*

4. The diameter of a ring is 1,5 what is the circumference? *Ans. 4,7 in.*

5. The diameter is 4,17 what is the circumference? *Ans. 13,10 in.*

PROBLEM III. *The circumference being known, to find the radius.*

RULE. Multiply the circumference by 0,159 and you will have the radius.

Example 1. To find the thickness of a column, its circumference has been measured with a string and found to be 12,542—required the radius.

```
  12,542
   0,159
 -------
  112878
  62710
 12542
 -------
1,994178 radius.
```

If 1,994 thousandths be the radius or half diameter, 3,988 will be the whole diameter of the column. Six figures are separated, because there are three in the multiplier, and 3 in the multiplicand. The three right hand decimals are unimportant.

2. The circumference of a column is 10,5 what is its radius? what its diameter? Radius 1.67 - Diam 3,34 -

3. The circumference of a ship's mast is $136^{\text{in.}},15$ what is its diameter? Ans. 43,28 in.

4. The circumference of a wheel is 48,75 what is its radius and diameter? Radius - 7,75
Diam. 15,5

PART II.

OF SURFACES.

PROBLEM I. *To find the surface of a parallelogram.*

RULE. The surface of a parallelogram (fig. 16,) or rectangle (fig. 14,) is found by multiplying the base by the height. That of a square is found by multiplying one of the sides by itself.

Example 1. A rectangle has $2^{\text{in.}},24$ for its base, $4^{\text{in.}},31$ for its height, what is its surface?

```
   2,24
   4,31
   ----
    224
   672
  896
  -----
  9,6544 surface.
```

That is, 9 square inches, and 65 hundredths of a square inch.

2. A room is 154,6 inches long, and 75,3 wide, what is its surface or area?

```
  154,6
   75,3
  -----
   4638
  7730
10822
-------
11641,38
```

That is, 11641 square inches, and 38 hundredths of a square inch.

3. A yard of a rectangular form, is 2023 inches long, and 1145 wide, what is its area or surface? . 293335

4. A house is 388 inches long, and 146 wide, how many square inches of ground does it cover? Ans. 56448

PROBLEM II. *The surface of an upright prism without including the two bases, is found by multiplying the height by the circumference of the base.*

All the lateral faces or sides of the body are rectangles, and come under the preceding rule.

Example 1. A man wishes to plaster the walls of the room mentioned in No. 1 of the last problem. These walls are 84,6 inches high, how many superficial inches do they contain? The room forms a parallelopiped, 2023 inches long, 1145 wide, and 84,6 high. Double the width and length, and add them together, and you have the whole length of the walls, 6336 inches. Multiply this by the height, and you have the answer in square inches.

```
1145          6336
1145          84,6
2023          ----
2023         38016
----        25344
6336       50688
           --------
           536025,6 square inches.
```

2. A man wishes to cover the walls of a room with cloth. The length of all the sides added together is 675 inches, 7 tenths, the height is 98,4 the cloth is 32 inches wide; how long a piece will cover the walls?

Multiply the length by the height, to find the surface or *superficies* to be covered. The cloth then must have a length which multiplied by its breadth will give the same superficies, and this is found by dividing the superficial contents of the walls by the width of the cloth.

Ans. 2077 inches or 57 yards.

Paper hangings may be measured in the same way.

If the prism be oblique, its surface is found by taking that of all the parallelograms which form it.

Problem III. *To find the surface of a triangle.*

Rule. Multiply the base by the height, and take half of the result.

If you please, you may take half the base or half the height, before you multiply, and then there will be no need of halving the result. A triangle is always the half of a parallelogram of the same base and height.

The pupil, it is to be hoped, need not be told that 12 inches make a foot, and 3 feet or 36 inches an English yard. We advert to this, because we have hitherto only measured by inches, and it may be well to say that when feet or yards, inches and decimals are named together, the yards or feet must be brought into inches. To do this, multiply the feet by 12, and the yards by 36. This however is not necessary, when only feet or yards are named, and the decimals are parts of them, and not parts of inches.

Thus, 8 feet, 4,8 inches are the same as 100,8 inches.
6 yds. 4,5 inches are equal to . . 220,5 inches.

Example 1. Required the extent of a field of a triangular shape, of which one side taken for the base, is 154

yards long, and the height (a perpendicular drawn from this base to the point or summit of the opposite angle) 83 yards. Multiply 77 (that is, half the base) by 83, and I have the answer, 6391 square yards of surface.

The superficies, or surface of a polygon, or a pyramid, is found by taking separately the surfaces of the triangles of which they are composed.

2. An irregular court has a quadrilateral *(four sided)* form. To find its surface, I measure one of the diagonals which I find to be 129,7 yards. I draw perpendiculars from the angles opposite this diagonal, one of which I find to be 52,5 yds. and the other, 41,8 yds. I consider the court as forming two triangles, and find their superficies separately, thus:

First triangle . .	129,7	Second triangle . .	129,7
Height	52,5		41,8
	6485		10376
	2594		1297
	6485		5188
	6809,25		5421,46
			6809,25
		2)	12230,71
		Square yards, . .	6115,355

But as this requires two multiplications, it is a shorter way to add the two heights, 52,5 and 41,8 which gives 94,3 of which the half, 47,15 multiplied by 129,7 the base, gives 6115,355 square yards as above.

3. A four sided polygon has a diagonal of 66 feet, 3,8 inches; the height of one triangle is 22 feet, 6 ,6 inches; and of the other, 18 feet, 8 ,2 inches; required the superficial contents of the polygon.

Ans. 195880,9 inches or
1360+ square feet.

If the polygon be regular, draw lines from the centre to two of the neighbouring angles, find the contents of the triangle thus formed, and multiply by the number of sides, which being all of a size, will make triangles of the same size.

~~Example 1.~~ A hexagonal basin has equal sides of 3,34 inches each. Its width from the centre of one side, to the centre of the opposite side, is 4,88 inches. As half of this line drawn from side to side is the height of one of the triangles, the height is, 2,44 inches. Multiply the base, which in this case is the side, by half the height, and you have the answer. Ans: 24,42 sq. in. 4

PROBLEM IV. *To find the surface of a trapezium.* (fig. 3.)

RULE. Take half the sum of the two parallel sides, and multiply by the height.

Example 1. A roof in the form of a trapezium, has one of its parallel sides 44,7 feet, and the other 33,5 feet in length, and the height is 9,4 feet, what is the superficies? *Ans.* 367,54 feet.

2. How many slates 15 inches long, and 12 wide, will cover the above roof? Ans. 294 slates.

Note. No allowance is here made for one slate's projecting over another, &c. This would only increase the size of the roof, but not alter the mode of calculation. Change the *feet* of the roof into *inches*; find the square inches in each slate, and divide the number of inches in the roof by the number in a slate.

PROBLEM V. *To find the surface, or superficial contents of a circle.*

RULE. Multiply the radius by itself, and then the product by $3\frac{1}{7}$ (or 3,143).

Example 1. A circular basin has a radius of 8,3 inches.

8,3	68,89
8,3	$3\frac{1}{7}$
249	20667
664	984
68,89	216,51 square in.

2. The radius of a cistern is 3,45 feet, what is its surface? Ans. 37,40 ft

3. I have measured round a basin, and find the distance 28,5 inches, and conclude by Problem III, Part I, that the radius is 4,53.—The rest of the work is done ~~by~~ like the above example. *Ans.* 64,49 square inches.

4. The circumference of a ~~wall~~ circle is found to be 4,85 feet, yds? what is its superficial contents? 1,76 sq. ft.

Problem VI. *To find the surface of an upright cylinder.* (4th Clas, fig. 12.)

Rule. Multiply the circumference of the base by the height.—As the base is a circle, knowing the radius, it is easy to find the circumference. (Prob. 2, Part I.)

Example 1. A painter has painted a circular hall, the walls are 3,4 yards high, and the diameter of the hall is 54,2 yards, how many square yards has he painted? *Ans.* 579,156 square yards.

If there be doors and windows, they are calculated separately, and subtracted from the amount. To find the contents of mouldings, measure them with a piece of string or parchment, which will yield to their various curvatures, and if you please, add their width and surface to the first amount.

PART III.

OF VOLUME.

PROBLEM I. *To find the volume of a prism or cylinder.*

RULE. Multiply the base by the height, and the product will be the number of cubes (that is, solid squares) contained in the body.

(length, [redacted] by the breadth & that by the height)

Note. The length, breadth, and height, must always be expressed in the same sort of measure, whether it be yards, feet or inches; if they are not so expressed in the proposition, they must be reduced before any thing else is done.

Example 1. A wall is 2,8 yards high; 0,6 thick; and 104,5 yards long; how many cubick feet does it contain?

2,8 multiplied by 0,6—gives 1,68 square yds.
1,68 multiplied by 104,5—gives 175,560 square yds.

2. A pile of wood in the form of a parallelopiped, is 54,8 feet long; 22,3 feet wide; and 37,1 feet in height; how many cubick feet does it contain? [redacted]

Multiply these three numbers together, and the answer will be 45337,684 cubick feet.

3. A cylindrical caldron is 8,3 feet deep, and 13 feet wide; what is its capacity (that is, how many cubick feet will it contain?)

The width or diameter is 13, the radius must be 6,5. Multiply 6,5 by 6,5 and the product by 3⅐ (Part [redacted] II. p[redacted]) and you have the superficies of the base, which multiply by the height 8,3 and you have the capacity required. *Ans.* 1102,124 ~~square~~ feet. cubick

4. A common brick is generally 8 inches long, 4 wide, and 2 thick. What is its volume? How many will it take to make a cubick foot of masonry? Vol. 64 sq. in 27 bricks cub. ft.

5. How many bricks will it take to construct a wall, 300 feet long, 6 feet high, and 1,5 thick?

Ans. 72900.

Note. It will be seen that this and the preceding calculation, make no allowance for mortar.

6. A well is 6,9 yards deep, and 1,2 yards in diameter. I wish to make a wall in it, 0,4 yards thick; how many cubick feet of stone will build it?

Calculate the well as if it were to be entirely filled up. Its diameter being 1,2 it radius must be half that, or 0,6 tenths; to this add, 0,4 tenths, the proposed thickness of the wall, and you have 10 tenths, or a whole yard, for the radius of the well.

Then subtract the empty part of the well, which forms another cylinder, whose radius is 0,6 tenths, as above mentioned.

1 multiplied by 1 and by $3\frac{1}{7}$ gives 3,14 the base of the first cylinder.

0,6 multiplied by 6 and by $3\frac{1}{7}$ gives 1,13 for the base of the smaller cylinder, which subtracted from 3,14 leaves 2,01 which multiplied by the height, gives the answer. *Ans.* 13,869 square yards.

7. How many bricks would the above wall require?

Ans. 10110,5.

Problem II. *To gauge a cask.*

Rule. Take the superficies of the base, and twice that of the centre at the bung hole, (Prob. 3, Part I.) add the two amounts, and multiply the product by a third of the length.

Note. All these measurements should be of the inside or clear, otherwise the thickness of the wood will be included.

Example 1. A cask is 31 inches in diameter at the bung, 28 at the base or head, and its length is 54 inches. What is its capacity?

The radius of the base is . . . 14
The radius of the bung is . . . 15,5

14 times 14	multiplied by $3\frac{1}{7}$	616
15 times 15,5	multiplied by do.	755
	Repeated	755
	Amount, neglecting fractions,	2126

Multiply this by 18, which is a third of the length, and you have the answer, 38268 cubick inches.

There are 231 cubick inches in a gallon. To find then how many gallons the above cask contains, divide its contents by 231.

2. Required the contents of a cask whose diameter at the bung is 38,6 inches, at the head or base 33,4 and whose length is 63,9 inches. Ans.^r 68540, 783 inches.

3. Required the contents of a cask whose *circumference* at the bung is 90 inches, at the base 80 inches, and whose length is 48 inches. Ans.^r 284115 cubick inches, 1229 Gallons

PROBLEM III. *To find the volume or solid contents of a pyramid or a cone.*

RULE. Multiply the base by the height, and take a third of the product.

Example 1. A loaf of sugar has a base 4,8 inches in diameter, and is 12,3 inches in height. What are its contents? the radius or half diameter

Find the contents of the base by multiplying 2,4 by 2,4 and the product by $3\frac{1}{7}$. Multiply the latter product by the height 12,3 and divide the product by 3 to find a third of it, which will be the answer.

Ans. 74,21 Cubic in. ~~Ans. 296,88 cubic in.~~

2. The base of a pyramid is a pentagon of equal sides, (2d Class, fig. 12.) each side being 14 inches. The height is 22 inches. What are its solid contents?

3. The base of a pyramid is a right angled triangle, (1st Class, fig. 9.) of which the base, or longest side, is 13 inches, the shortest 6. The height of the pyramid is 19 inches. Required the solid contents.

Find the superficies of the base by Prob. I, Part I.

PROBLEM IV. *To find the volume or solid contents of a truncated cone of parallel bases.*

Note. A truncated cone is one whose top is cut off.

RULE. Multiply the radius of each base by itself, and multiply them together. Add together the three products. Multiply the whole sum by the height, and add to this product a third of a ninth of it, (that is, a 27th.)

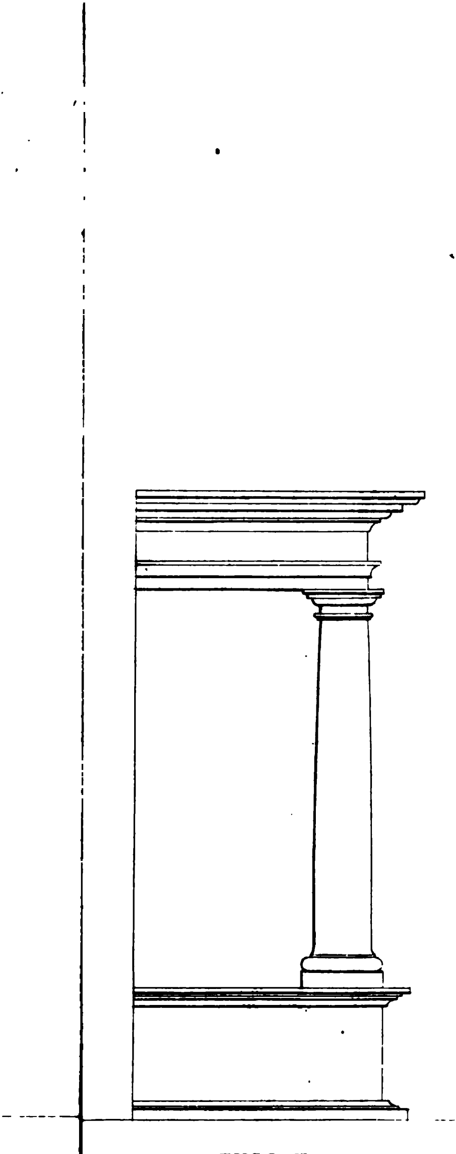
Example 1. A bucket is 14,5 inches in diameter at top, and 11,2 at bottom. Its *perpendicular* height is 17,5 inches. Required its solid contents.

14,5 multiplied by 14,5 gives	210,25
11,2 multiplied by 11,2 gives	125,44
14,5 multiplied by 11,2 gives	162,40
	498,09

498 multiplied by the height 17,5 gives . . .		8715
A ninth of which is	968,3	
And a third of the ninth is		322,7
Cubick inches,		9037,7

2. How many such buckets of water would it take to fill the caldron mentioned in Example 3, Prob. I. of this Part?

END.



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